# Key indicator

This page is a companion to the [WMO State of the Global climate](https://library.wmo.int/index.php?lvl=notice_display&id=97) reports. It provides access to the latest versions of selected key global indicators used in the report.

Global climate indicators (for an overview see [Trewin et al. 2021](https://journals.ametsoc.org/view/journals/bams/102/1/BAMS-D-19-0196.1.xml)) provide a broad view of climate change at the largest scale, encompassing the composition of the atmosphere, energy changes, and the responses of the land, ocean, and ice. These indicators are closely related to one another. For example, the rise in CO2 and other greenhouse gases in the atmosphere leads to an imbalance of energy and thus warming of the atmosphere and ocean. Warming of the ocean in turn leads to rising sea levels, to which is added the melting of ice on land in response to increasing atmospheric temperatures.

The global indicators draw on a wide range of data sets, which are listed at the bottom of the page. Differences between data sets for the same indicator indicate the degree of uncertainty in the indicator. Figures are updated at least annually, with some data sets being updated more frequently.

Under each of the figures, you will find links to the images in multiple file formats (png, pdf and svg), as well as a set of data as shown in the figure in [a common comma-separated values (csv) format](https://help.ceda.ac.uk/article/105-badc-csv). The “Read more” link will take you to a wider range of linked indicators.

## What the IPCC says

Regarding the large-scale changes in the climate, Working Group 1 from the sixth assessment report of the Intergovernmental Panel on Climate Change concluded that:

[A.1](https://www.ipcc.ch/report/ar6/wg1/resources/spm-headline-statements#:~:text=A.1%C2%A0%C2%A0It%20is%20unequivocal%20that%20human%20influence%20has%20warmed%20the%20atmosphere%2C%20ocean%20and%20land.%20Widespread%20and%20rapid%20changes%20in%20the%20atmosphere%2C%20ocean%2C%20cryosphere%20and%20biosphere%20have%C2%A0occurred) It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.

[A.2](https://www.ipcc.ch/report/ar6/wg1/resources/spm-headline-statements#:~:text=A.2%C2%A0%C2%A0The%20scale%20of%20recent%20changes%20across%20the%20climate%20system%20as%20a%20whole%20%E2%80%93%20and%20the%20present%20state%20of%20many%20aspects%20of%20the%20climate%20system%20%E2%80%93%20are%20unprecedented%20over%20many%20centuries%20to%20many%20thousands%20of%20years) The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years.

[A.3](https://www.ipcc.ch/report/ar6/wg1/resources/spm-headline-statements) Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5.

# Monthly Key Indicators

Global climate indicators (for an overview see [Trewin et al. 2021](https://journals.ametsoc.org/view/journals/bams/102/1/BAMS-D-19-0196.1.xml)) provide a broad view of climate change at the largest scale, encompassing the composition of the atmosphere, energy changes, and the responses of the land, ocean, and ice. These indicators are closely related to one another. For example, the rise in CO2 and other greenhouse gases in the atmosphere leads to an imbalance of energy and thus warming of the atmosphere and ocean. Warming of the ocean in turn leads to rising sea levels, to which is added the melting of ice on land in response to increasing atmospheric temperatures.

The global indicators draw on a wide range of data sets, which are listed at the bottom of the page. Differences between data sets for the same indicator indicate the degree of uncertainty in the indicator. Figures are updated monthly, with some data sets being updated more or less frequently.

Under each of the figures, you will find links to the images in multiple file formats (png, pdf and svg), as well as a set of data as shown in the figure in [a common comma-separated values (csv) format](https://help.ceda.ac.uk/article/105-badc-csv). The “Read more” link will take you to a wider range of linked indicators.

# Greenhouse gases

Greenhouse gases are gases such as Carbon Dioxide (CO2) and Methane (CH4) that absorb and re-emit infrared radiation. In the atmosphere, their interaction with infrared radiation ultimately leads to a warming of the atmosphere and surface.

Atmospheric concentrations of greenhouse gases reflect a balance between emissions from human activities (such as the burning of fossil fuels), natural sources, and sinks in the biosphere and ocean. Increasing levels of greenhouse gases in the atmosphere due to human activities have been the major driver of climate change since the mid-twentieth century. Global average mole fractions of greenhouse gases (as shown in the figures) are calculated from in situ observations made at multiple sites in the [Global Atmosphere Watch (GAW) Programme](https://public.wmo.int/en/programmes/global-atmosphere-watch-programme) of WMO and partner networks.

The ocean is a sink for CO2. Some of the excess CO2 in the atmosphere is absorbed by the ocean. CO2 reacts with seawater and lowers its pH. This process is known as ocean acidification.

## What the IPCC says

[A 1.1](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=4) Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO2), 1866 parts per billion (ppb) for methane (CH4), and 332 ppb for nitrous oxide (N2O) in 2019. Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO2 emissions from human activities over the past six decades, with regional differences (high confidence).

# Global temperature

A key indicator of climate change is the global mean temperature. Global mean temperature measures the change in temperature near the surface of the Earth and averaged across its surface. Increased concentrations of greenhouse gases in the atmosphere are the primary driver of the long-term increase in global mean temperature.

[The Paris Agreement](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement) aims to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change. The Paris Agreement is generally understood to refer to long-term changes in temperature, so a single year that exceeds 1.5°C would not necessarily signal a breach of the threshold.

Warming of the Earth is not the same everywhere. The land has warmed more rapidly than the ocean and the rate of warming has been highest in the Arctic, which has warmed around two to four times faster than the global mean depending on the time period chosen.

## What the IPCC says

[A.1.2](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) Each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C higher than 1850–1900. Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C). The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C). Additionally, methodological advances and new datasets contributed approximately 0.1°C to the updated estimate of warming in AR6.

[A.1.3](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) The likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is likely that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is very likely that well-mixed GHGs were the main driver of tropospheric warming since 1979 and extremely likely that human-caused stratospheric ozone depletion was the main driver of cooling of the lower stratosphere between 1979 and the mid-1990s.

# Ocean indicators

The ocean covers nearly 70% of the Earth’s surface. Most of the excess energy that accumulates in the Earth system due to increasing concentrations of greenhouse gases is taken up by the ocean. The added energy warms the ocean and this warming causes the water to expand, which in turn leads to sea-level rise. The melting of ice on the land also adds to sea level rise. The surface layers of the ocean have warmed more rapidly than the deeper interior, mirrored in the rise of global mean sea-surface temperature and in the increased incidence of marine heatwaves.

As the concentration of CO2 in the atmosphere increases, so too does the concentration of CO2 in the ocean. This affects ocean chemistry, lowering the average pH of the water, a process known as ocean acidification, though it should be noted that the ocean remains, on average, slightly alkaline. All these changes have a broad range of impacts and interactions in the ocean and coastal areas.

## What the IPCC says

[A1.6](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) It is virtually certain that the global upper ocean (0-700 m) has warmed since the 1970s and extremely likely that human influence is the main driver. It is virtually certain that human-caused CO2 emissions are the main driver of current global acidification of the surface open ocean. There is high confidence that oxygen levels have dropped in many upper ocean regions since the mid-20th century and medium confidence that human influence contributed to this drop.

[A1.7](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea level rise was 1.3 [0.6 to 2.1] mm/yr between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm/yr between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm/yr between 2006 and 2018 (high confidence). Human influence was very likely the main driver of these increases since at least 1971.

[Chapter 2](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter02.pdf#page=5) Ocean pH has declined globally at the surface over the past four decades (virtually certain) and in all ocean basins in the ocean interior (high confidence) over the past 2-3 decades. A long-term increase in surface open ocean pH occurred over the past 50 million years (high confidence), and surface ocean pH as low as recent times is uncommon in the last 2 million years (medium confidence)

[Chapter 9](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter09.pdf#page=17) Since the 1980s [marine heatwaves] have also become more intense and longer. Satellite observations and reanalyses of SST show an increase in intensity of 0.04°C per decade from 1982 to 2016, an increase in spatial extent of 19% per decade from 1982 to 2016, and an increase in annual MHW days of 54% between the 1987–2016 period compared to 1925–1954. The SROCC assessed that 84–90% of all MHWs that occurred between 2006 and 2015 are very likely caused by anthropogenic warming. There is new evidence since SROCC that the frequency of the most impactful marine heatwaves over the last few decades has increased more than 20-fold because of anthropogenic global warming. In summary, there is high confidence that MHWs have increased in frequency over the 20th century, with an approximate doubling from 1982 to 2016, and medium confidence that they have become more intense and longer since the 1980s

# Sea ice extent

Sea ice is ice that floats on the surface of the ocean. It affects the transfer of heat, energy, momentum and gases between the atmosphere and ocean. Sea ice also plays an important role in many polar ecosystems. Sea-ice extent is a measure of the area of the ocean covered by sea ice.

Sea ice reflects sunlight and absorbs relatively little compared to dark ocean water. If sea ice cover is reduced, the surface absorbs far more sunlight and warms up. In turn the warming can reduce sea ice cover. This feedback is one reason that the Arctic has warmed faster than the global average.

The formation and persistence of sea ice is different in the northern and southern hemispheres. In the northern hemisphere, ice forms largely within the confines of the Arctic ocean, which is enclosed by the coasts of the northern land masses, and other partly enclosed seas. In the southern hemisphere, the ice forms around the edge of the Antarctic continent.

Because sea ice is floating ice, melting and growth of sea ice have little effect on sea level.

## What the IPCC says

[A1.5](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) Human influence is very likely the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (decreases of about 40% in September and about 10% in March). There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability.

[Chapter 2](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter02.pdf#page=5) Current Arctic sea ice coverage levels are the lowest since at least 1850 for both annual mean and late-summer values (high confidence) and for the past 1000 years for late-summer values (medium confidence). Between 1979 and 2019, Arctic sea ice area has decreased in both summer and winter, with sea ice becoming younger, thinner and more dynamic (very high confidence). Decadal means for Arctic sea ice area decreased from 6.23 million km2 in 1979–1988 to 3.76 million km2 in 2010–2019 for September and from 14.52 to 13.42 million km2 for March. Antarctic sea ice area has experienced little net change since 1979 (high confidence), with only minor differences between sea ice area decadal means for 1979–1988 (2.04 million km2 for February, 15.39 million km2 for September) and 2010–2019 (2.17 million km2 for February, 15.75 million km2 for September)

# Glaciers and ice sheets

Glaciers are formed by snow that falls and compacts into solid ice. The ice can flow downhill and where it reaches warmer altitudes, or reaches the sea, the ice can melt or break off in chunks. Large continuously glaciated areas are known as ice sheets. Currently, there are two ice sheets found on Greenland and Antarctica.

Observations and measurements of glaciers and ice sheets shown that they have been losing mass in the past few decades.

## What the IPCC says

[A1.5](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) Human influence is very likely the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979-1988 and 2010-2019 (decreases of about 40% in September and about 10% in March). There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability. Human influence very likely contributed to the decrease in Northern Hemisphere spring snow cover since 1950. It is very likely that human influence has contributed to the observed surface melting of the Greenland Ice Sheet over the past two decades, but there is only limited evidence, with medium agreement, of human influence on the Antarctic Ice Sheet mass loss.

# Precipitation

Precipitation includes rain, snow, sleet, and hail that falls to the ground. Too much or too little precipitation can have significant socioeconomic and environmental impacts and can lead to flooding and drought. Precipitation is measured at weather stations and rain gauges around the world. There is no single key global indicator associated with precipitation, but as local variations in precipitation are linked to local impacts, maps of precipitation quantiles (which categorise precipitation according to whether it is in the top 20% and 10% or lowest 20% and 10%) and anomalies (differences from the long-term average) are shown here. Global and regional patterns of rainfall are affected by short-term climate drivers such as the El Nino Southern Oscillation and the North Atlantic Oscillation.

## What the IPCC says

[A.1.4](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=5) Globally averaged precipitation over land has likely increased since 1950, with a faster rate of increase since the 1980s (medium confidence). It is likely that human influence contributed to the pattern of observed precipitation changes since the mid-20th century and extremely likely that human influence contributed to the pattern of observed changes in near-surface ocean salinity.

[A.3.2](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf#page=8) The frequency and intensity of heavy precipitation events has increased since the 1950s over most land area for which observational data are sufficient for trend analysis (high confidence), and human-induced climate change is likely the main driver. Human-induced climate change has contributed to increases in agricultural and ecological droughts in some regions due to increased land evapotranspiration (medium confidence).

# co2

Carbon dioxide (CO2) is one of the most important greenhouse gases. The concentration of CO2 in the atmosphere is measured at stations around the world which are combined to provide a globally representative value.

# ch4

Methane (CH4) is an important greenhouse gas. The concentration of CH4 in the atmosphere is measured at stations around the world which are combined to provide a globally representative value.

# n2o

Nitrous oxide (N2O) is an important greenhouse gas. The concentration of N2O in the atmosphere is measured at stations around the world which are combined to provide a globally representative value.

# tas

Global mean temperature is based on measurements made at weather stations over land and by ships and buoys over the ocean. Temperatures are typically expressed as anomalies which are temperature differences from the average for a standard period. Here, 1850-1900 is used for the global mean. Instrumental temperature records are some of the longest climate records available, with some series extending back to the 17th century.

# lsat

Land surface air temperature is the temperature of air approximately 2m above the surface. It is measured at weather stations around the world. The thermometers used are typically housed in screens that shield the thermometer from direct sunlight, while allowing air to circulate freely.

# sst

Sea-surface temperature (SST) is the temperature of the surface ocean, typically measured in the upper metre, or metres of the ocean, by ships, buoys and satellites.

# ohc

Ocean heat content is a measure of the change in heat energy stored in the subsurface ocean. It is based on temperature measurements made by research vessels (since the 1950s), moorings, and automated profiling floats (known as Argo floats) since the 2000s.

# sealevel

Global mean sea level is a measured by satellites using radar altimeters that record the time taken for a radar signal to reach the sea-surface and return to the satellite. Longer records of sea level (not shown here) exist based on tide gauge measurements made along coastlines around the world since the late 19th century.

# ph

Ocean pH is a measure of how acid/alkaline the ocean surface water is. The ocean surface is typically slightly alkaline, however, increasing concentration of CO2 in the water is driving a decline in pH known as ocean acidification.

# mhw

Marine heatwaves (MHWs) are categorized as moderate when the sea-surface temperature (SST) is above the 90th percentile of the climatological distribution for five days or longer; the subsequent categories are defined with respect to the difference between the SST and the climatological distribution average: strong, severe or extreme, if that difference is, respectively, more than two, three or four times the difference between the 90th percentile and the climatological distribution average (Hobday et al., 2018).

# mcs

Marine cold spells (MCSs) are categorized as moderate when the sea-surface temperature (SST) is below the 10th percentile of the climatological distribution for five days or longer; the subsequent categories are defined with respect to the difference between the SST and the climatological distribution average: strong, severe or extreme, if that difference is, respectively, more than two, three or four times the difference between the 10th percentile and the climatological distribution average (Hobday et al., 2018).

# glacier

Glaciers are measured using a variety of different techniques. Glacier mass balance data for the global network of reference glaciers are available from the World Glacier Monitoring Service (WGMS), https://www.wgms.ch.

# greenland

The Greenland ice sheet mass balance measures the change in ice mass of the Greenland ice sheet. The change in mass is estimated in three principle ways: gravimetric measurements, altimetric measurements and the input-output method. Gravimetric measurements infer mass changes from variations in the Earth’s gravitational field as measured by the GRACE and GRACE-FO (Gravity Recovery and Climate Experiment – Follow On) satellites. Altimetric measurements, measured the height of the ice sheet surface, using radar and laser altimeters. Input-output methods, use weather conditions from a numerical weather prediction model, to estimate changes in mass balance at the surface of the ice sheet. These are combined with estimates of mass loss from glaciers around the edge of Greenland and melting on the underside of the glaciers. The IMBIE data set combines over 25 different estimates of Greenland mass balance to get a comprehensive view of the long-term changes.

# antarctica

The Antarctic ice sheet mass balance measures the change in ice mass of the Antarctic ice sheet. The change in mass is estimated in three principle ways: gravimetric measurements, altimetric measurements and the input-output method. Gravimetric measurements infer mass changes from variations in the Earth’s gravitational field as measured by the GRACE and GRACE-FO (Gravity Recovery and Climate Experiment – Follow On) satellites. Altimetric measurements, measured the height of the ice sheet surface, using radar and laser altimeters. Input-output methods, use weather conditions from a numerical weather prediction model, to estimate changes in mass balance at the surface of the ice sheet. These are combined with estimates of mass loss from glaciers around the edge of the continent and melting on the underside of the glaciers. The IMBIE data set combines many estimates of Antarctic mass balance to get a comprehensive view of the long-term changes.

# arctic ice

Sea-ice concentrations are estimated from microwave radiances measured from satellites (from 1979). Sea-ice extent is calculated as the area of ocean grid cells where the sea-ice concentration exceeds 15%. Although there are relatively large differences in the absolute extent between data sets, they agree well on the year-to-year changes and the trends.

# antarctic\_ice

Sea-ice concentrations are estimated from microwave radiances measured from satellites (from 1979). Sea-ice extent is calculated as the area of ocean grid cells where the sea-ice concentration exceeds 15%. Although there are relatively large differences in the absolute extent between data sets, they agree well on the year-to-year changes and the trends.

# short\_term\_climate\_drivers

Climate modes are recurrent patterns, usually of pressure or sea-surface temperature (SST), typically characterized by negative and positive phases, which each have distinctive effects on the distribution of rainfall, temperature and other meteorological elements on time scales varying from days to seasons and beyond.

# precip\_quantiles\_9month

Precipitation quantiles are based on the nine months aggregated GPCC Monitoring Product and First Guess Monthly product. The baseline period is 1991-2020, using Full Data Monthly in its latest version. Quality controlled rain gauge (in situ) data are used and the quality control protocol depends on the data set. The percentiles are not calculated for those grid cells, where the precipitation total aggregated in the reference period is below ten millimetres.

# precip\_quantiles\_12month

Precipitation quantiles are based on the twelve months aggregated GPCC Monitoring Product and First Guess Monthly product. The baseline period is 1991-2020, using Full Data Monthly in its latest version. Quality controlled rain gauge (in situ) data are used and the quality control protocol depends on the data set. The percentiles are not calculated for those grid cells, where the precipitation total aggregated in the reference period is below ten millimetres.

# Terminate

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